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# Accelerated expansion of the Universe driven by dynamic self-interaction

A.B. Balakin [a,*], H. Dehnen [b]

[a] Department of General Relativity and Gravitation, Kazan State University, Kremlevskaya str. 18, Kazan 420008, Russia
[b] Universität Konstanz, Fachbereich Physik, Fach M 677, D-78457, Konstanz, Germany

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ABSTRACT

We establish a new model, which takes into account a dynamic (inertial) self-interaction of gravitating systems. The model is formulated by introduction of a new function depending on the square of the covariant derivative of the velocity four-vector of the system as a whole into the Lagrangian. This term is meant for description of both self-action of the system irregularly moving in the gravitational field, and back-reaction of the motion irregularities on the gravity field. We discuss one example of exact solution to the extended master equations in the framework of cosmological model of the FLRW type with vanishing cosmological constant. It is shown that accelerated expansion of the Universe can be driven by traditional matter with positive pressure (e.g., dust, ultrarelativistic fluid) due to the back-reaction of the gravity field induced by irregular motion of the system as a whole; this back-reaction is shown to be characterized by the negative effective pressure.



## 1. Introduction

The observational fact that the Universe expands with acceleration is till now a puzzle for theoretical cosmology. One can formulate three main ideas, on which the explanations of this phenomenon could be based. The first idea is that there exists some exotic substratum, Dark Energy, possessing a negative effective pressure (see, e.g., [1–3] for review and references). The second one is focused on modifications of the so-called geometric sector of relativistic theory of gravity: one can mention, for instance, $f(R)$ theory, the Gauss–Bonnet model, etc. (see, e.g., [4–6] for review and references). The Lagrangians of such theories contain the invariants constructed with nonlinear combinations of the Ricci scalar and the Riemann and Ricci tensors. The third idea introduces interactions of new types between gravity on the one hand, and fields and matter on the other hand (see, e.g., [7–10]). The Non-Minimal Field Theory is the most elaborated trend in this direction, and the corresponding models can be described by introduction of cross-invariants into the Lagrangian, which contain all admissible convolutions of the Riemann, Ricci tensors and Ricci scalar in combinations with the field strength tensors (see, e.g., [8,9,11]).

The theory of dynamic self-interaction of gravitating systems, which we establish here, is in line with the third idea. The motivation of the dynamic extension of the gravitational theory has two aspects: mathematical and physical ones. Started from the mathematical point of view, one can see that pure geometrical objects, which we use in the Lagrangian of the gravity field (the Riemann, Ricci tensors and Ricci scalar), contain second order partial derivatives of the metric. Since the covariant derivative of the metric itself is considered to be equal to zero, there are no geometric invariants containing the first derivatives of the metric only. Moreover, the covariant derivative of the scalar field reduces to the partial derivative, the field strength tensors for the electromagnetic and gauge fields, being the skew-symmetric quantities, in fact do not contain the Christoffel symbols, the four-divergence of the vector potential is assumed to be vanishing due to the Lorentz gauge. Thus, the Lagrangians of the Einstein–Maxwell, Einstein–Yang–Mills–Higgs, etc. theories do not contain invariants, into which only the first derivatives of the metric enter. The situation changes essentially, when it is acceptable to introduce into the Lagrangian the invariants containing the covariant derivative of the velocity four-vector, attributed to the macroscopic motion of the system as a whole. In this case one deals with the non-vanishing first derivatives of the metric, and such a gravitational

* Corresponding author.
*E-mail addresses:* Alexander.Balakin@ksu.ru (A.B. Balakin), Heinz.Dehnen@uni-konstanz.de (H. Dehnen).

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